Geostationary Lightning Mapper (GLM)

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Instrument Requirements

Tom Dixon (GSFC) - Instrument Manager

- Mission Objectives:
  - *Provide continuous full-disk lightning measurements for storm warning and nowcasting*
  - *Provide longer warnings of tornado activity*
  - *Accumulate a long-term database to track decadal changes in lightning activity*

Instrument Requirements
(going into Formulation Phase)

- *Full-disk coverage*
- *Flash POD: 70% threshold at EOL (99% goal)*
- *Flash FAR: < 5%*
- *Ground Sample Distance: 10 km threshold; 0.5 km goal*
- *Pointing knowledge: 4 km threshold; 2 km goal*
- *Flash intensity to within 10%. Pulse detection of O(1 ms).*
- *Reliability > 0.6 after 10 yr MMD 8.4 yr; Design Life 10 yr.*

Acquisition Status

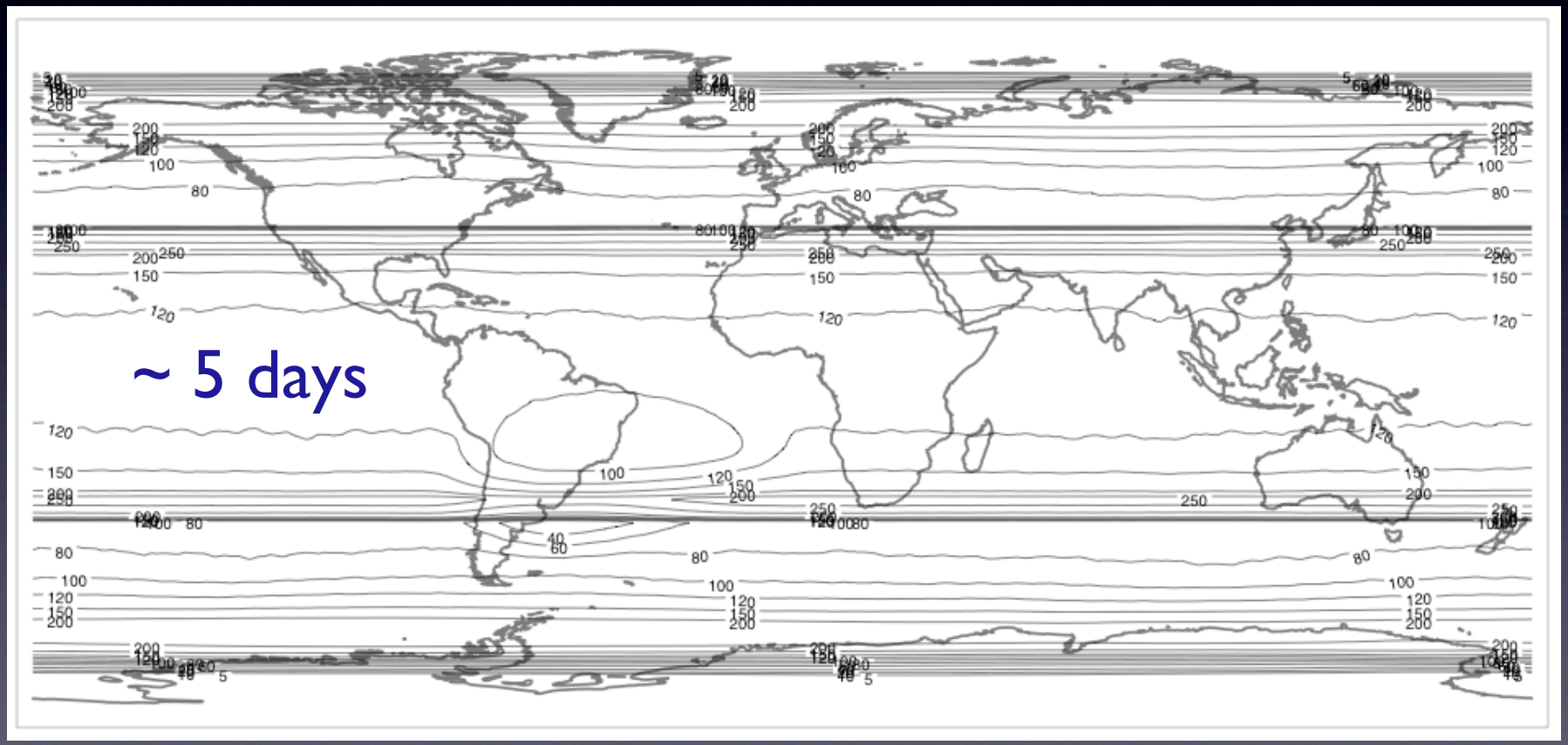
- Three 1-year, $2M Formulation Studies awarded in February 2006
- Ball Aerospace, ITT Industries, Lockheed Martin
- Trade studies, Concept Design
  - *Requirements Analysis, System Configuration & Coverage*
  - *Solar Intrusion*
  - *Focal Plane Architecture*
  - *Ground Truth Verification*
  - *Yaw Flip*

NASA Low Earth Orbit Precursors

- NASA / MSFC Optical Instruments
- OTD (1995-2000), LIS (1997-present)
- Daytime & nighttime lightning detection
- Intracloud (IC) & Cloud-to-Ground (CG) detection
- 8 km (OTD); 4 km (TRMM/LIS) nadir resolution
- 50% - 90% Detection Efficiency
- 128x128 CCD pixel arrays; 500 fps; narrowband filter; full-frame readout with frame-differencing based event detection

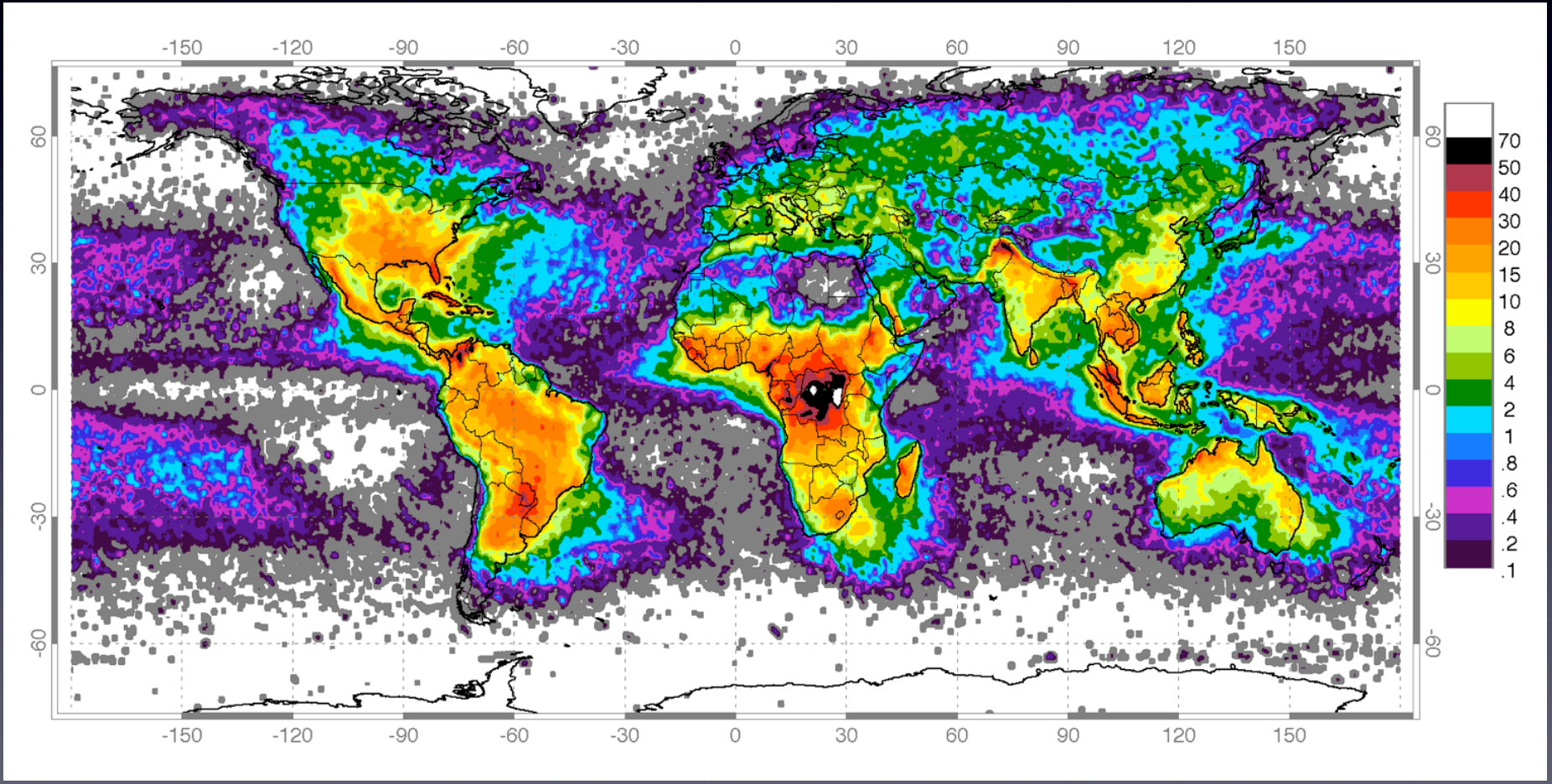
NASA LEO Precursors

Total viewing to date, OTD+LIS.
GLM sampling over Americas will exceed ΣLEO within 2 weeks.



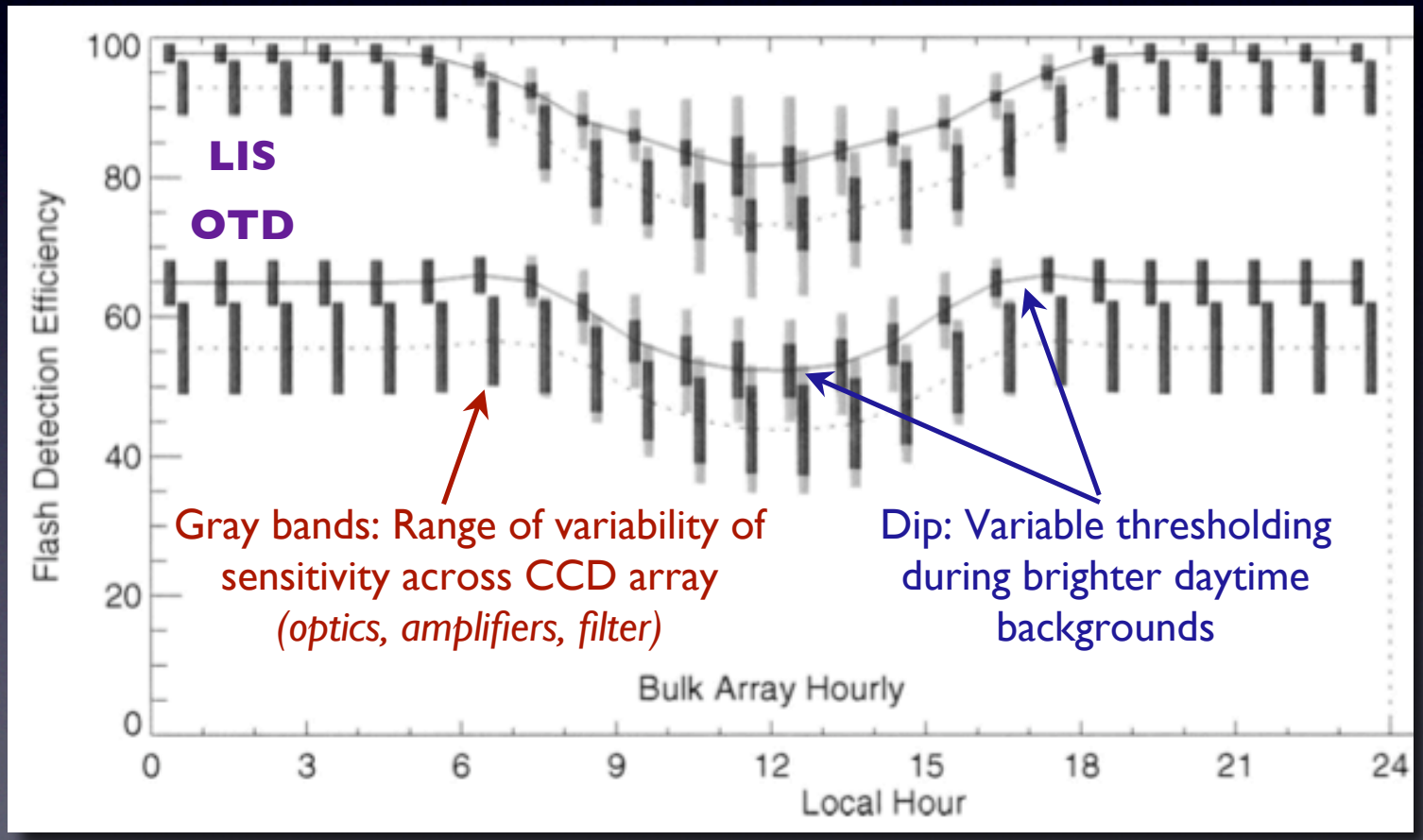
NASA LEO Precursors

Climatology - *flashes / km^2 / year*



NASA LEO Precursors

15 - 20% day / night variation in flash Detection Efficiency (POD)

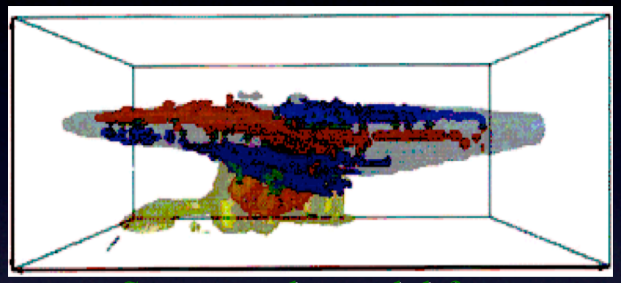


NASA / MSFC Risk Reduction

- Algorithm readiness
  - "Virtual GLM" - LIS, LMA
  - Real-time filtering, clustering, tracking algorithms
  - Resolution improvement, real-time validation
- Forecast applications
  - Nowcasting, HSV GLM supersite, data assimilation, NPOESS virtual radar
  - Washington DC VHF network
- Radiance data mining
  - Flash energetics, IC/CG classification, improved ground network utilization

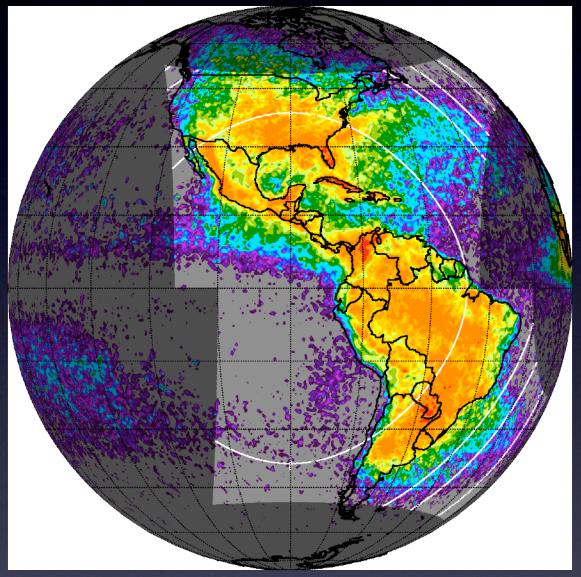
Continuous GEO Total Lightning
will identify severe storm potential

Process physics understood



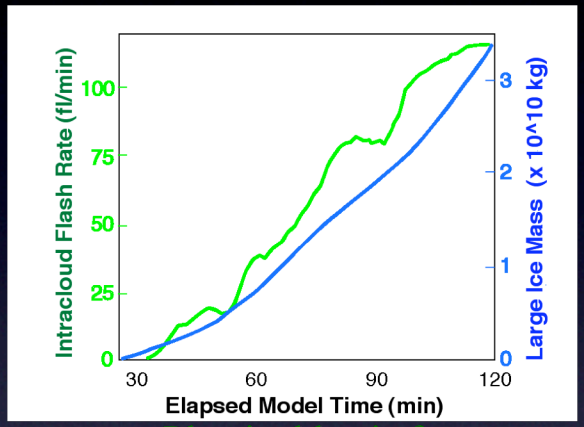
Storm-scale model for decision support system

GLM GOES E View



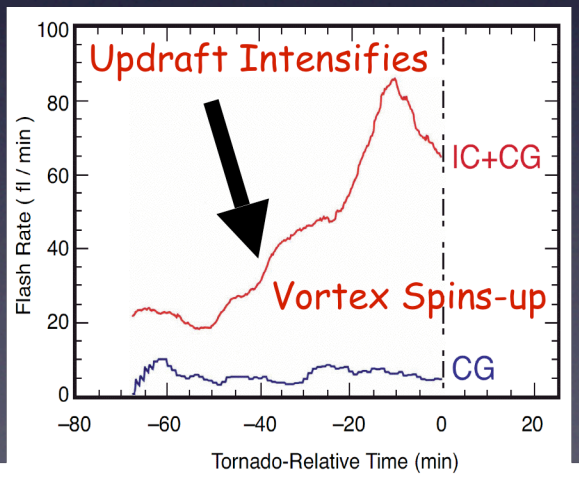
Demonstrated in LEO with OTD & LIS

Ice flux drives lightning



Physical basis for improved forecasts

IC flash rate controlled by graupel (ice mass) production (and vertical velocity)



Lightning jump precedes severe weather

Lightning improves storm predictability

Forecast Usage

April 8 2006 HUN Severe Wx - Chris Darden, NWS:

"...As for [total lightning] during the warning process, it certainly did factor into the supercell that strengthened across northern Limestone/Madison Counties ... There was a very nice jump/surge with this one as the rotational couplet tightened. We noticed this in real-time during our "weather watch"..."

Total lightning has directly contributed to several correct severe warning decisions at HUN, OHX and BMX.

Forecast Usage

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE HUNTSVILLE AL
838 PM CDT TUE APR 18 2006

AFTER AN ACTIVE LATE AFTERNOON/EARLY EVENING...SUPERCELL CONVECTION HAS SHIFTED S AND DIMINISHED. GREAT CALL BY THE DAY SHIFT AT BRIEFING TIME...AS THE STATIONARY BOUNDARY THAT LAY ACROSS NE AL LIT UP QUICKLY AROUND 21Z. THE STRONGEST CELLS TRACKED SOUTH ALONG THE BOUNDARY AND DEVELOPED DEEPER ROTATION WITH TIME...AND EXHIBITED STRONG LMA SOURCE DENSITY SIGNALS DURING ROBUST UPDRAFT PERIODS ALSO SHOWN IN THE HIGH VIL/LRM3 REFLECTIVITY FIELDS. LOW LEVEL LAPSE RATES (0-2KM) WERE QUITE STEEP BASED UPON THE KBMX SOUNDING AT 00Z. SIG SVR PARAMETER WAS FAIRLY HIGH THIS EVENING ALONG THIS BOUNDARY TOO. EFFECTIVE DEEP LAYER SHEAR WAS UP TO 40-50KT...SO WITHIN THE ZONE FOR SUPERCELLS. LOW LEVEL SHEAR AND LOW LCLS WERE SOMEWHAT LACKING FOR TORNADOGENESIS.

Southern Thunder Workshop

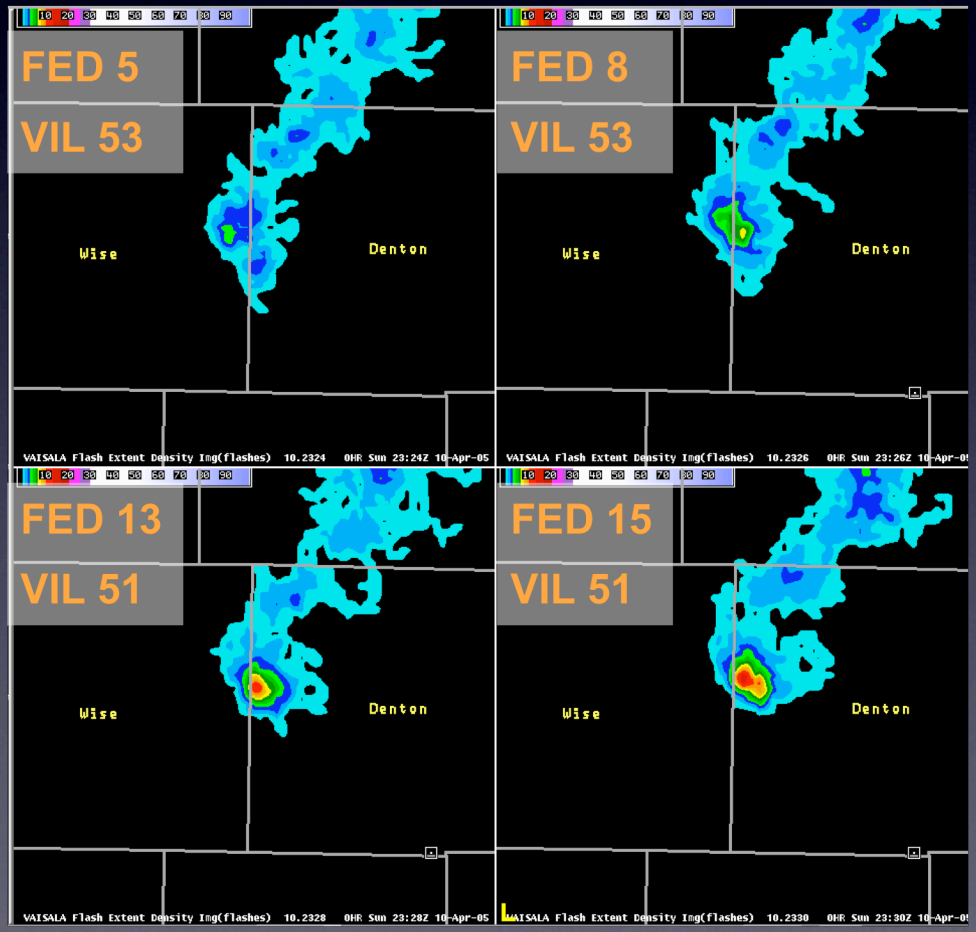
July 2005 - weather.msfc.nasa.gov/sport

- HUN forecaster survey benchmarking: In 9 of 16 cases, positive impact (1-7 min increased lead time) *[Buechler - SPoRT / UAH]*

		80 warnings	*41 warnings*
Warning Variable Ranking	All surveys	Severe storms	Tornado
Reflectivity signatures	9.1	8.7	9.7
Total lightning	6.7	7.0	6.2
Near storm environment	5.8	5.2	6.8
Eyewitness report	5.2	4.1	7.7
Strong rotation	5.2	3.2	9.3
Boundaries	3.8	3.4	4.5
Cloud-to-ground lightning	3.7	3.7	4.0
TVS	2.3	1.5	3.8
Previous severe WX	1.5	0.2	4.5

Southern Thunder Workshop

- "Total lightning has proven invaluable in aviation forecasting, specifically with regard to inclusion or exclusion of thunderstorms in TAFs. Flash Extent Density imagery helps forecasters visualize and understand the thunderstorm and CG lightning threat." *[Patrick - NWS / DFW]*

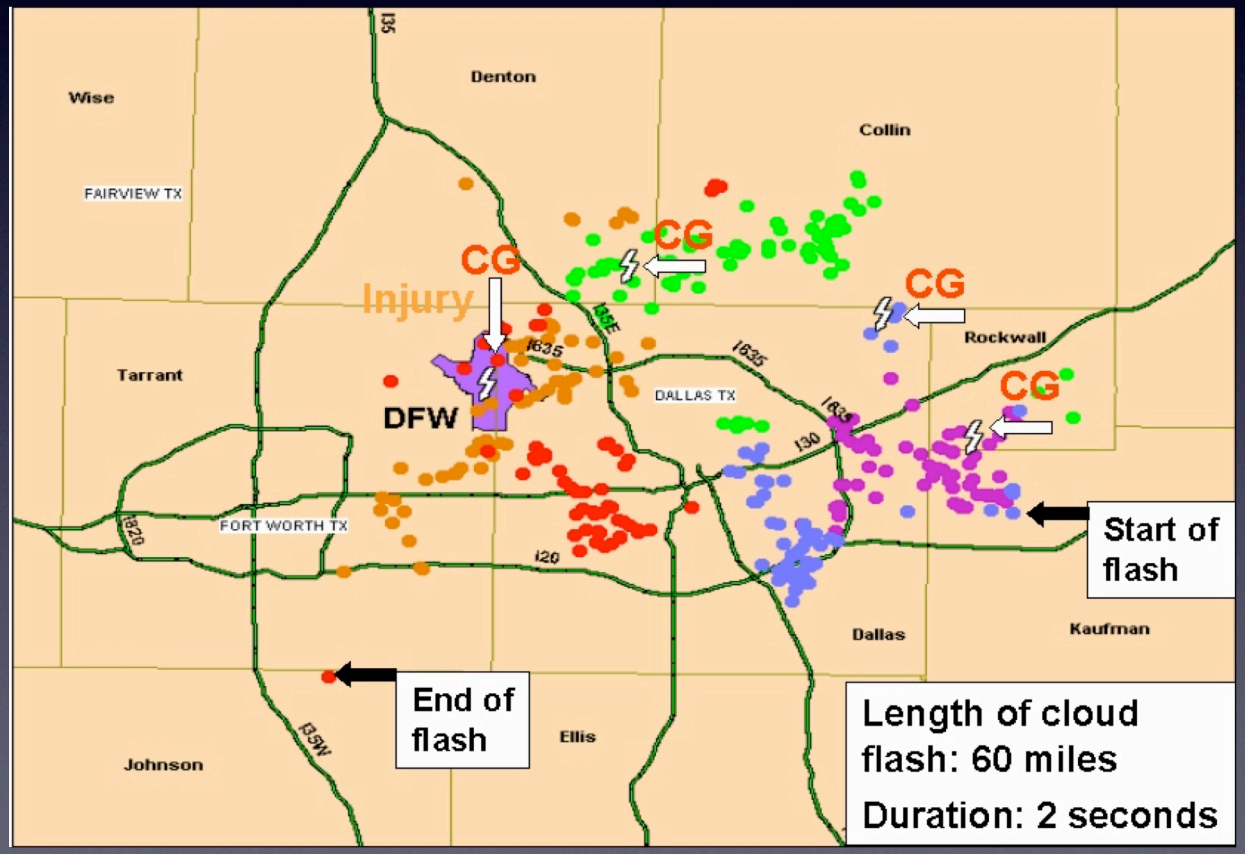


2-minute updates

Southern Thunder Workshop

- "[VHF] total lightning data provides clear advantages over the combination of radar and CG lightning for properly identifying the CG lightning hazard region" *[Demetriades - Vaisala]*

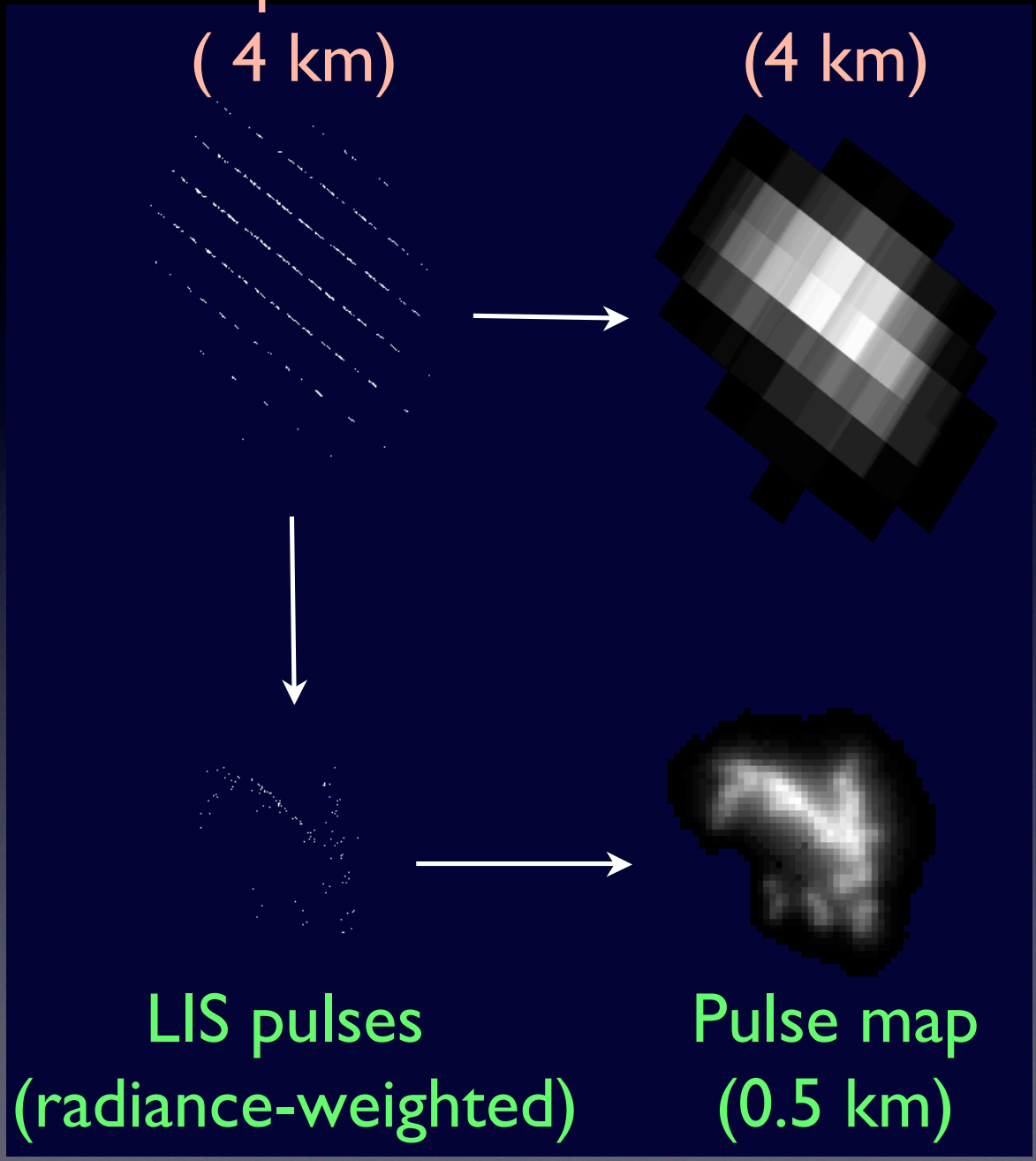
Spider flash at 15:15 Z on 17 Aug 2001
Lightning warning at DFW was no longer in effect when this occurred

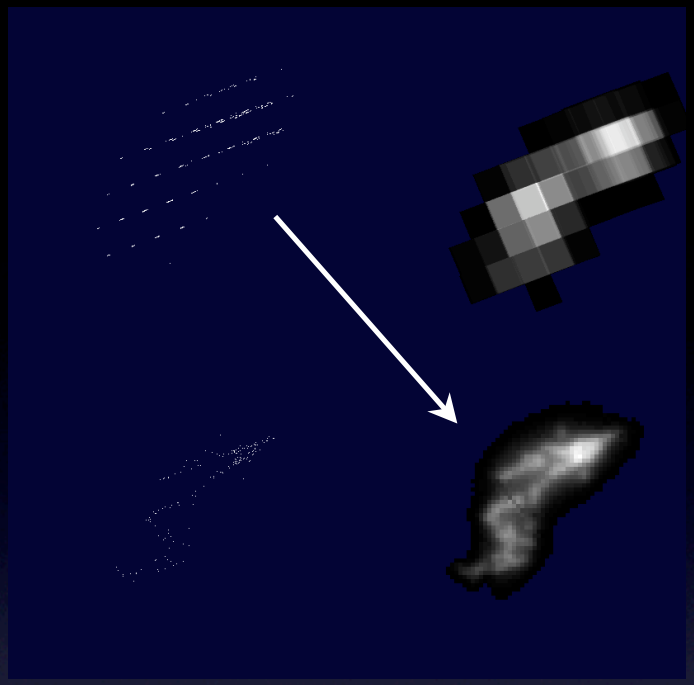


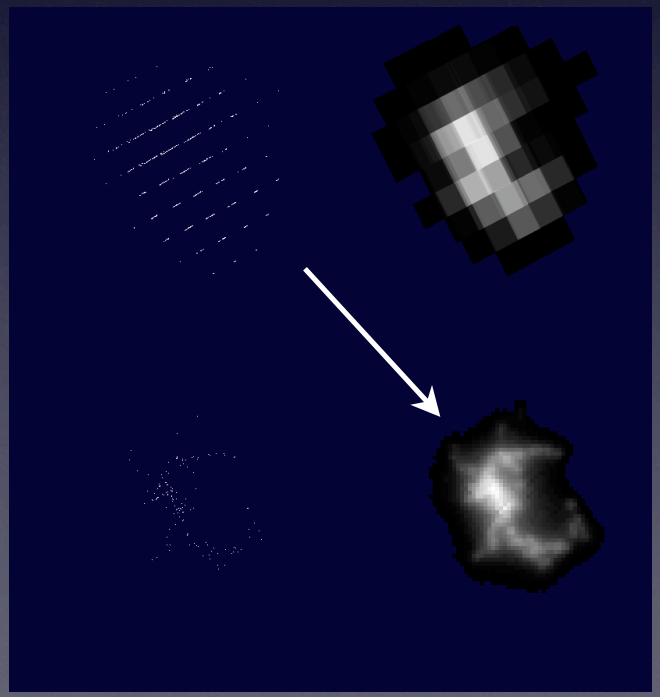
Risk Reduction:
Effective Resolution

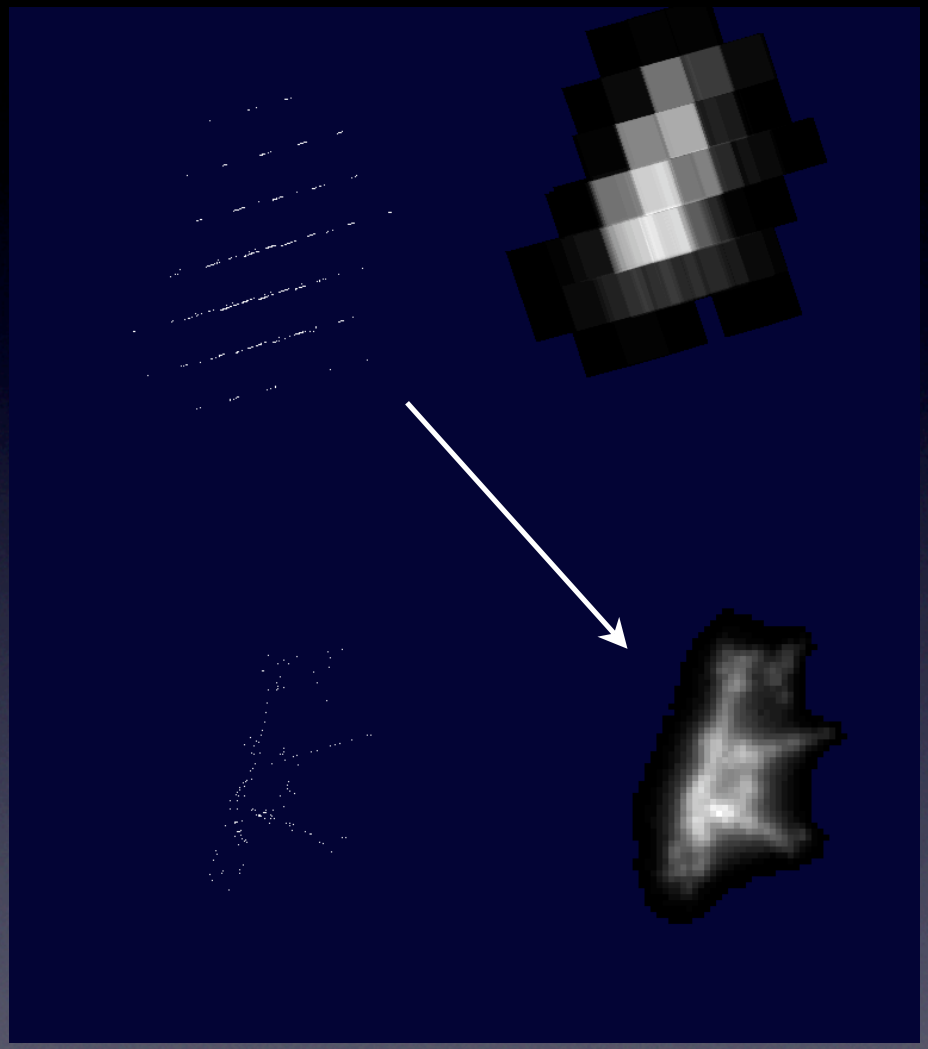
- Flashes are composed of many pulses
- Each pulse may illuminate several pixels
- The *radiance-weighted centroid* of these pixel clusters provides information at higher resolution than the GSD
- Often, these pulse centroids can be used to trace out actual lightning channels
- The flash centroid can be computed at much higher resolution than the pixel GSD

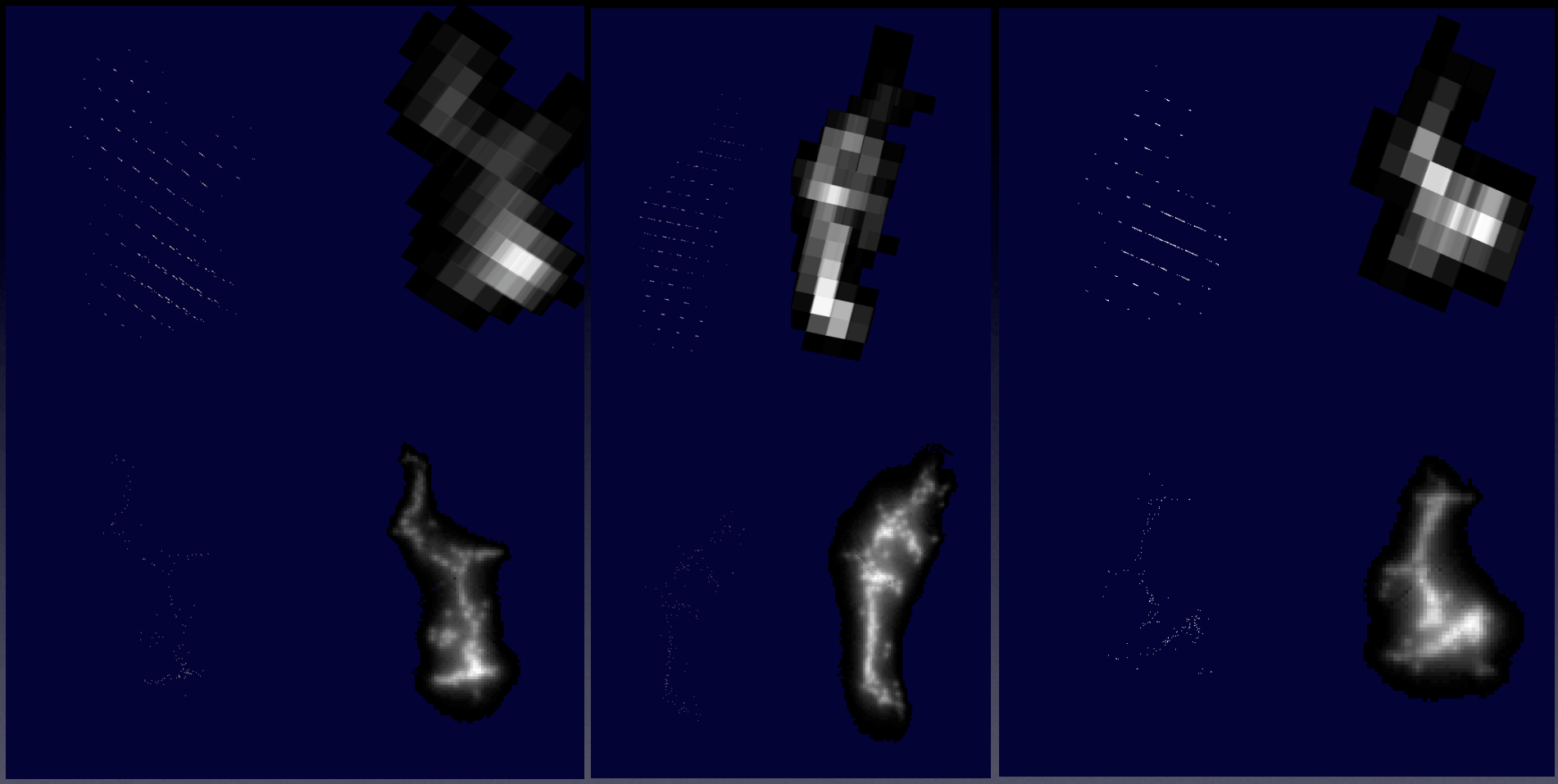
Effective Resolution











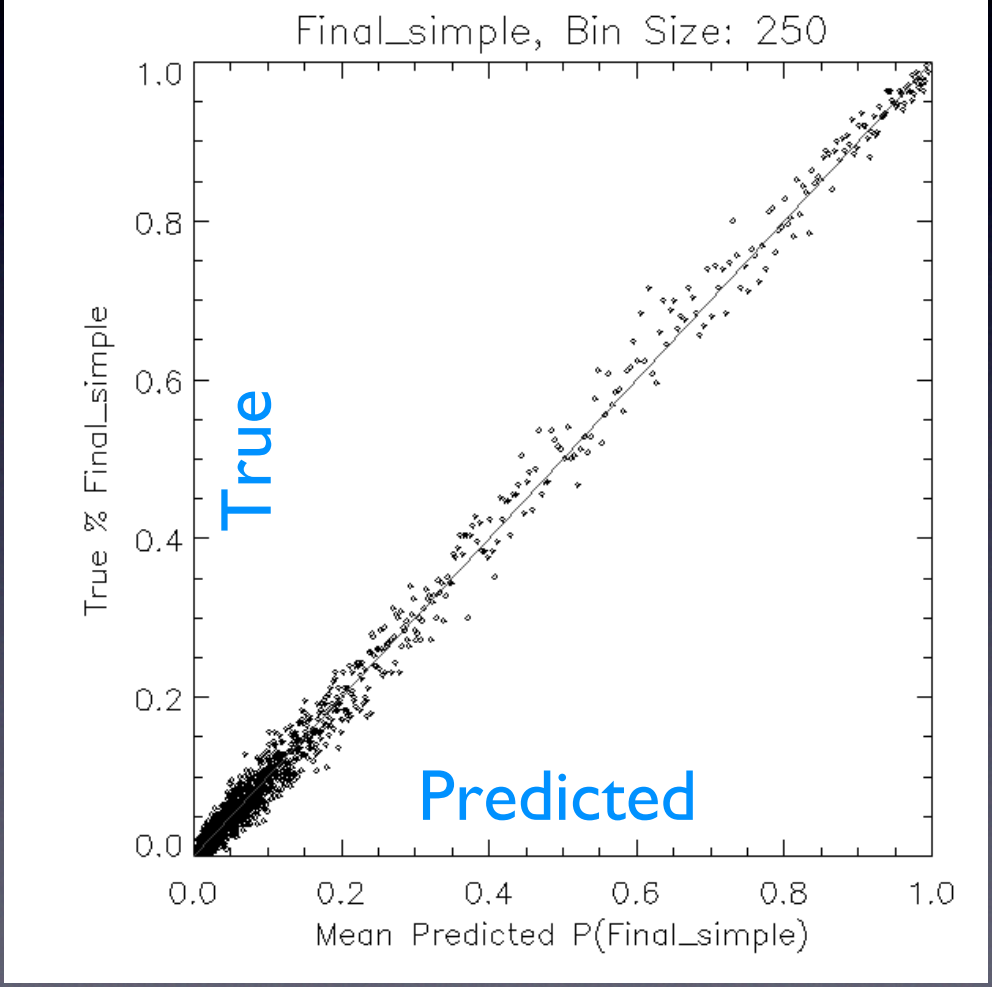
Risk Reduction:
Intracloud vs Cloud-to-Ground Discrimination

- High altitude aircraft studies suggested that optical classification of IC vs CG not possible
- But
  - *Small sample size*
  - *Simple, univariate classifiers*
  - *FAR, not FAT used to disqualify (at that time, interest was CG warning, not forecast improvement)*

Risk Reduction:

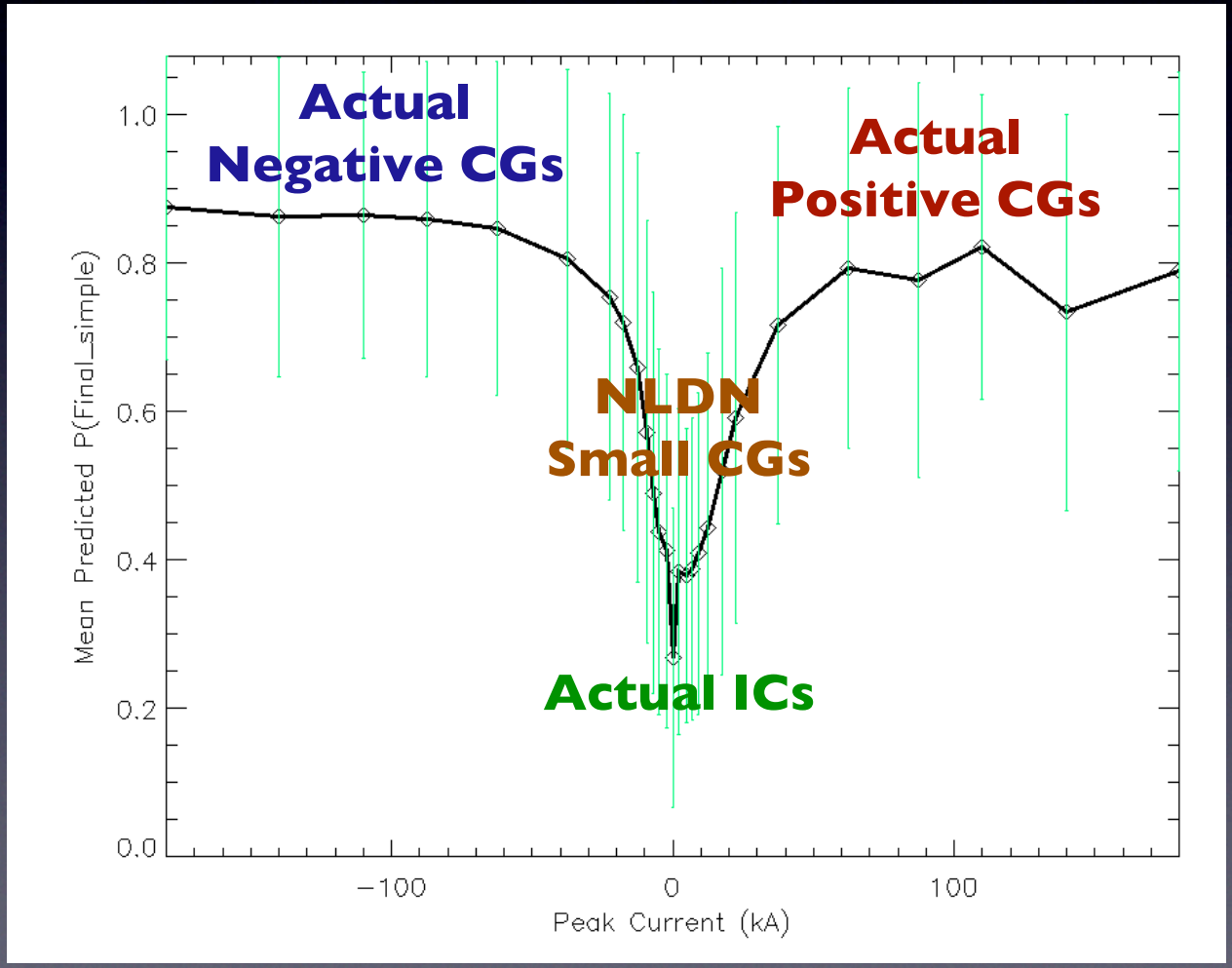
IC vs CG Discrimination

Optical neural network CG classifier: *Unbiased*



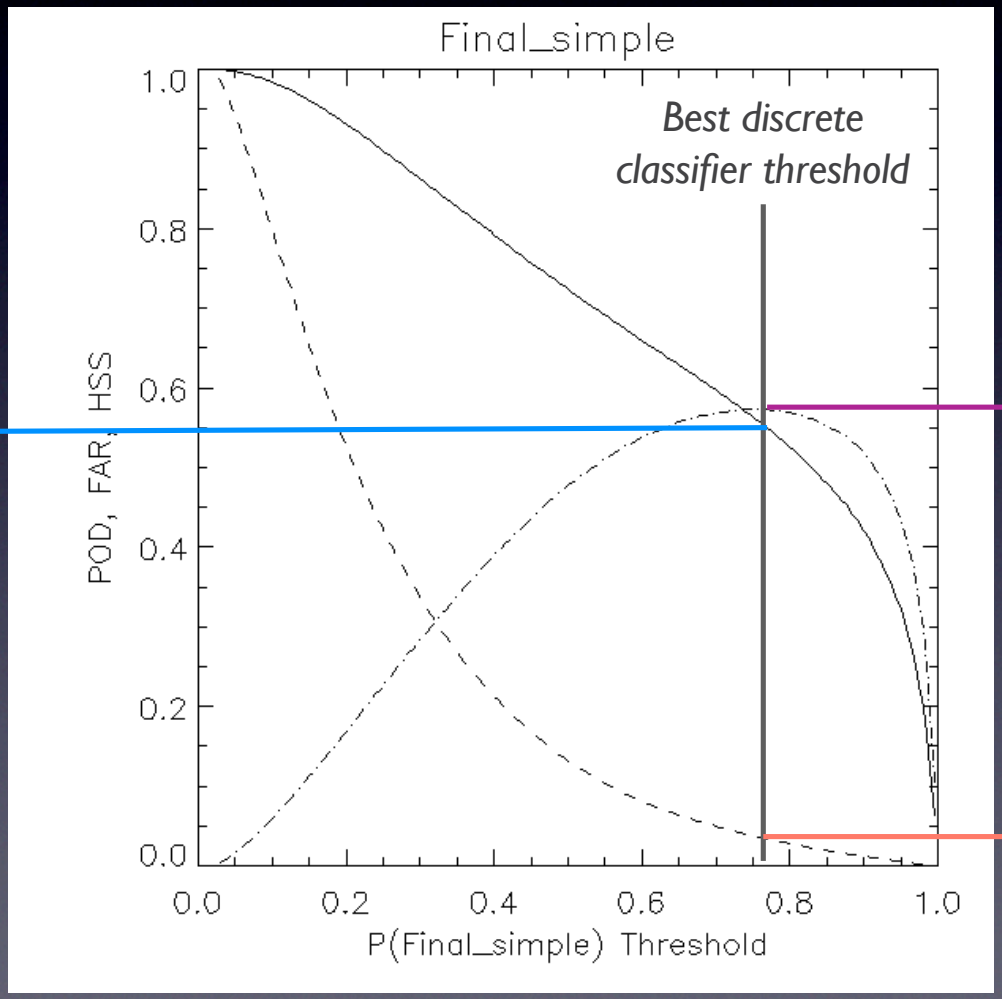
Risk Reduction:

IC vs CG Discrimination



Risk Reduction:

IC vs CG Discrimination



POD ~ 55%

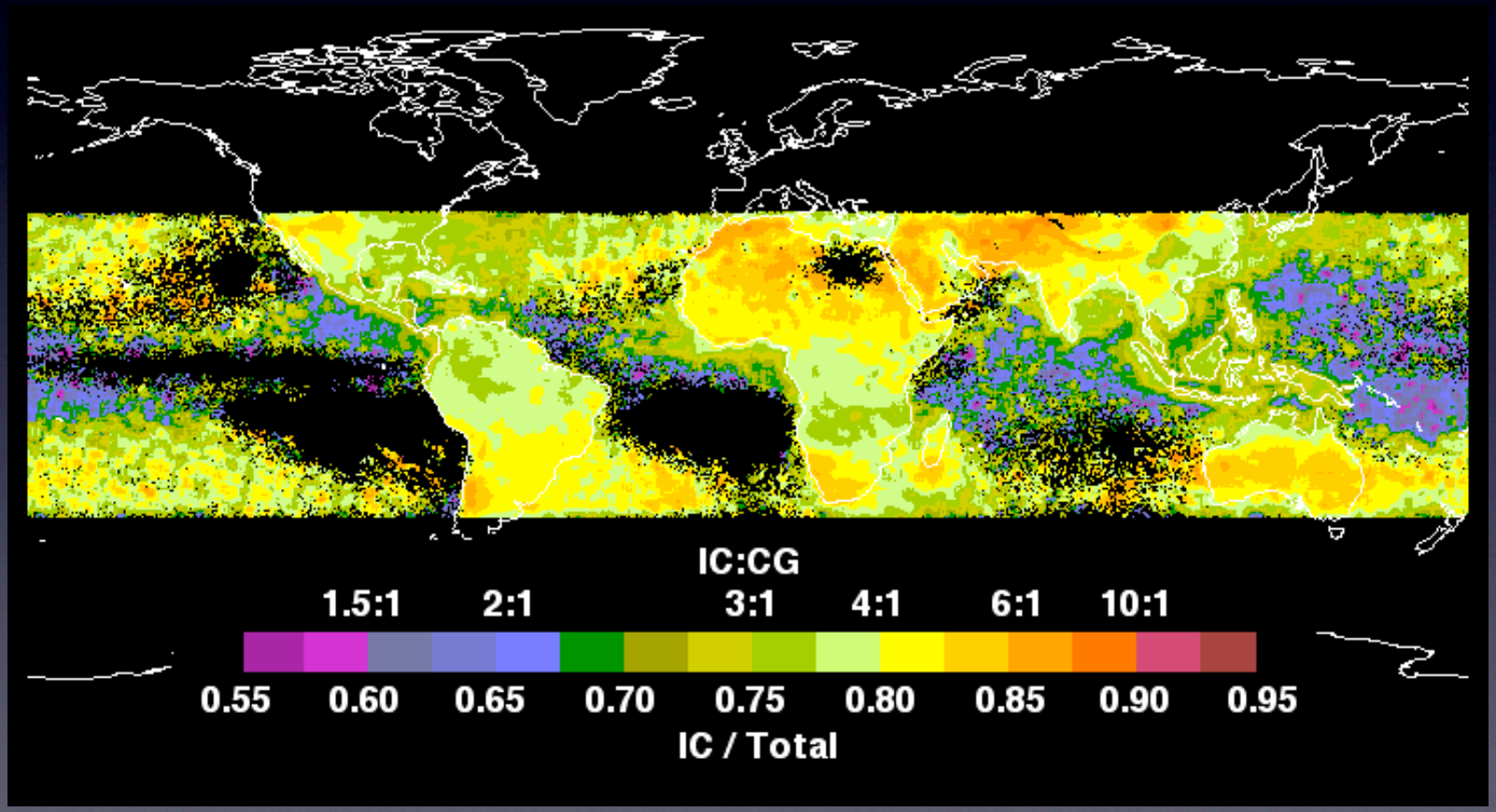
HSS ~ 58%

FAT ~ 4%

* First-generation neural network classifier. Early results from a machine learning class at Univ. CO / Boulder suggest 75% HSS, 1% FAT from random forest (bagged) classifiers

Risk Reduction:

IC vs CG Discrimination



Risk Reduction:

NPOESS Synergy - Virtual Radar

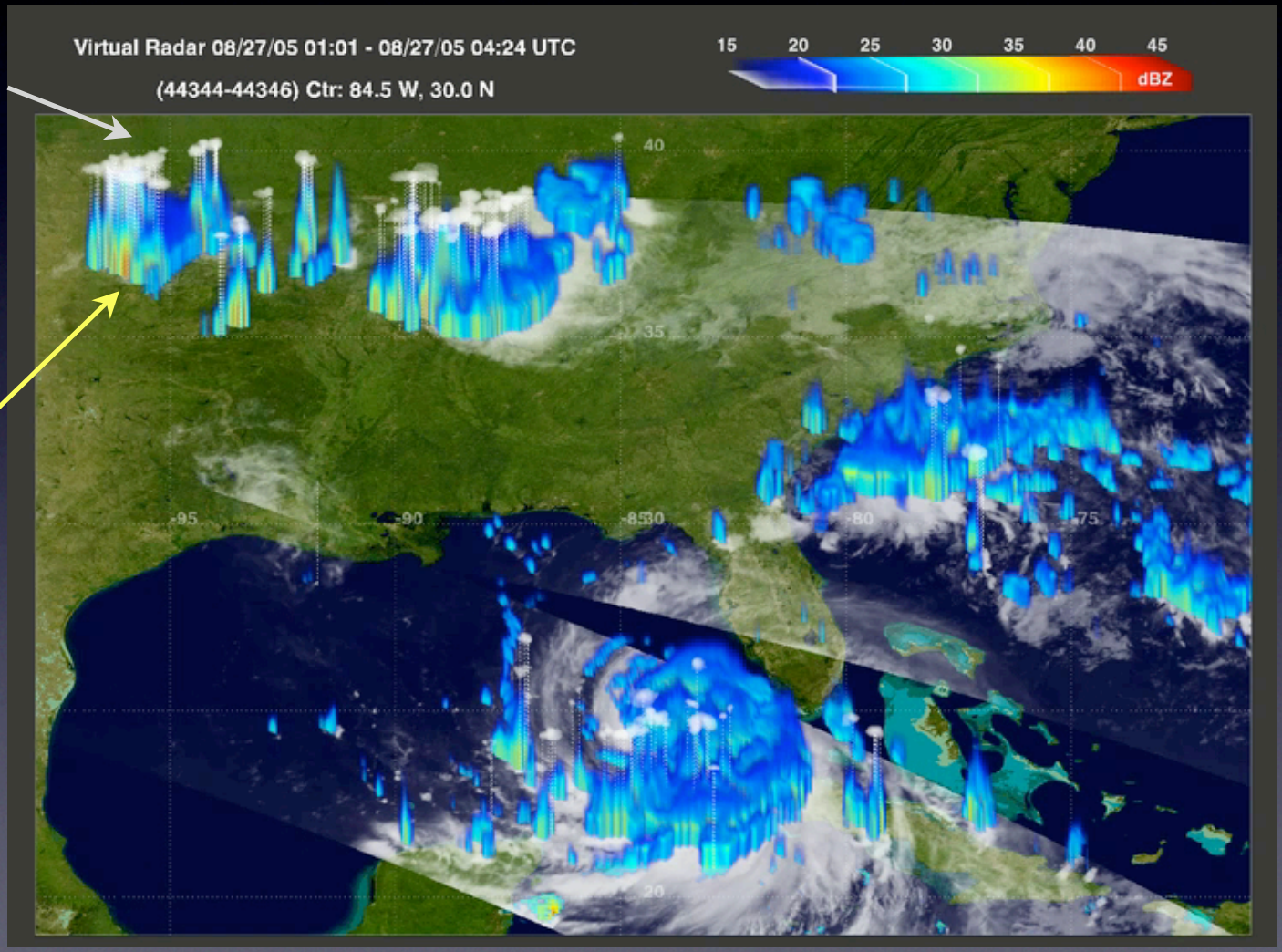
- From TRMM, we can retrieve equivalent radar reflectivity vertical profiles from passive microwave (TMI, AMSR-E, GMI, CMIS)
- Lightning boosts retrieval skill up to 20% for some parameters (C/S, IWC, Echo Tops, SHI)

Risk Reduction

NPOESS Synergy - Virtual Radar

Contributing total lightning

PM-retrieved volumetric reflectivity



GLM vs Ground Network Comparison

	CG POD	IC POD	IC/CG Classification	Day/Night Stability	Res'n / Accuracy	Coverage
GLM	H	H	M (Statistical)	M-L (known)	M	H
VHF Local	H	H	H (Manual)	L	H	L
CONUS LF/MF	H	L	M-H (small "CG" issues)	L	H	M
Offshore LF/MF	L	-	-	H	L-M	H

Conclusions

- 1/4-way through formulation
- Significant, diverse forecast applications studies underway using local VHF networks in Melbourne, Huntsville, Dallas, Norman, and soon, Washington DC & White Sands
- Rapid update (1 min or less); strong correlation with ice mass; day/night stability; offshore viewing are key discriminators for severe weather and aviation applications
- Total lightning data already being used operationally by forecasters, in AutoNowcaster, etc

weather.msfc.nasa.gov/sport

- Emerging products from LIS (high resolution channel maps, IC and CG classification, etc) will be very mature by GOES-R